Hybrid Renewable Energy Sources for Control Strategies of a Fuzzy Controlled Grid Connected System Fed PMSM Drive Applications

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Abstract: Renewable energy, such as wind, solar energy, is desirable for power generation due to their unlimited existence and environmental friendly nature. This paper deals with system integration and fuzzy logic based controller design for power management of a grid connected Hybrid renewable energy source (HRES). The hybrid system is the combination of photovoltaic (PV) array, fuelcell, and battery storage via a common current source interface multiple-input dc-dc converter. This converter is used to integrate the renewable energy sources to the utility grid. All MPPT methods follow the same goal that is maximizing the PV system output power by tracking the maximum power on every operating condition. Maximum power point tracking technique (Incremental conductance) for photovoltaic systems was introduced to maximize the produced energy. The coordination of two control modes, coordination of the PV array and the PEMFC in the hybrid system, and determination of reference parameters are presented. The proposal operating strategy systems with a flexible operation mode change always operate the PV array at maximum output power and the PEMFC in its high efficiency performance band. Also thus improving the performance of system operation, enhancing system stability, and reducing the number of operating mode changes. The proposed concept can be implemented to PMSM Drive system hybrid PV/PEMFC/Battery using PMSM drive applications using Matlab/Simulink software.

Keywords: Fuel Cell, Battery, Distributed Generation, Photovoltaic Cell, Fuzzy Control.

I. INTRODUCTION

The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. At that time, economic issues were the most important factors, hence interest in such processes decreased when oil prices fell. The current resurgence of interest in the use of renewable energy is driven by the need to reduce the high environmental impact of fossil-based energy systems. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time [1]. Future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades. Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not "dispatch able"—the power output cannot be controlled. Daily and seasonal effects and limited predictability result in intermittent generation. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well [2]. Industry must overcome a number of technical issues to deliver renewable energy in significant quantities. Control is one of the key enabling technologies for the deployment of renewable energy systems. Solar and wind power require effective use of advanced control techniques.

In addition, smart grids cannot be achieved without extensive use of control technologies at all levels [3]. The penetration level of green and renewable energy sources/distributed generation units are expected to grow in the near future as there is a probability of rundown conventional fuels for power generation. The distributed generation is classified as renewable and non-renewable. The distributed generation sources such as Fuel cells, Wind and Solar energy are increasing daily due to increase in demand for electrical power [4-7]. These energy sources are environmental friendly, reduces transmission and distribution losses, peak load shaving, can be used as backup sources and etc. Fuel cell is a promising device as it is efficient, modular and can be placed at any site for improving system efficiency [8] but it has slow start-up response. Solar energy is an important renewable energy source [9] but the intermittent nature of this technology is a major issue. The availability of energy is driven by weather and cell temperature but not on the loads of the systems. This technology can be labeled as intermittent and normally PV array uses a Maximum Power Point Tracking (MPPT) technique to continuously deliver the highest power to the load when there are variations in irradiation and temperature [10]. Because of the intermittent nature of PV array it becomes an uncontrollable source. In order to overcome the drawbacks with the slow start-up of fuel cells and intermittent nature of PV cell a fuzzy controlled grid connected hybrid photovoltaic and proton

exchange membrane fuel cell distributed generation system with battery as energy storage is proposed in this paper.
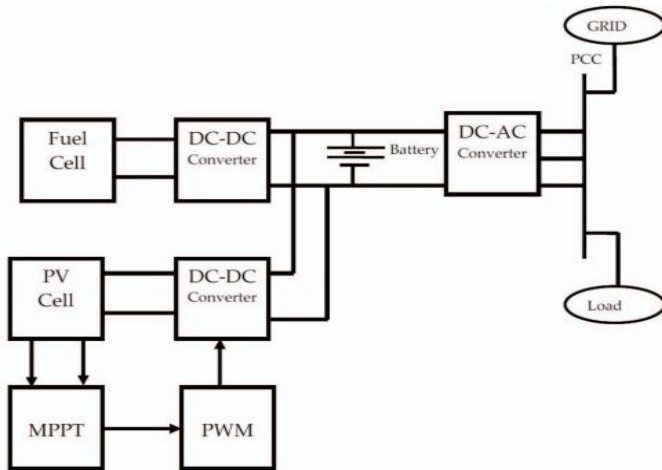
II. SYSTEM MODELING

Fig.1.Block Diagram of Grid connected Hybrid system.

The grid connected hybrid system consists of a PV/PEMFC/Battery hybrid source with the main grid connecting loads at the Point of Common Coupling (PCC) as shown in Fig.1. The PV/PEMFC/Battery and the dc–dc converters are connected on the common DC bus which is coupled at the dc side of a dc/ac inverter.

A. Proton Exchange Membrane Fuel Cell Model

A fuel cell operates like a battery by converting the chemical energy into electrical energy, but it differs from a battery in that as long as the hydrogen and oxygen is supplied it will produce DC electricity continuously. Fuel cells play a vital role in distributed generation because of their advantages such as high efficiency, no pollutant gases and modular structure flexibility. The fuel cell voltage is described by a relationship given below [2]

$$E = E_{Nernst} - V_{act} - V_{ohm} - V_{conc} \tag{1}$$

Where Enerst is the "thermodynamic potential" of Nerst, which represents the reversible (or open-circuit) voltage of the fuel cell the performance of the fuel cell is affected by many parameters and one important parameter is reactant utilization, Uf[6] and is given by equation (2)

$$U_f = 1 - \frac{q_{H2}^{out}}{q_{H2}^{in}} = \frac{q_{H2}^{r}}{q_{H2}^{in}} = 2K_r I \tag{2}$$

The Nernst's equation and ohm's law determine the average voltage magnitude of the fuel cell stack and is given by equation (3)

$$V_{fc} = N_0 \left(E_0 + \frac{RT}{2F} \left(\ln \left(\frac{P_{H_2} P_{O_2}^{05}}{P_{H_2O}} \right) \right) - rI_{fo} \right) \tag{3}$$

$$P_{H_2} = -\frac{1}{t_{H_2}} \left(P_{H_2} + \frac{1}{K_{H_2}} \left(q_{H_2}^{in} - 2K_r I_{fc} \right) \right) \tag{4}$$

$$P_{H_2O} = -\frac{1}{t_{H_2O}} \left(P_{H_2O} + \frac{2}{K_{H_2O}} K_r I_{fc} \right) \tag{5}$$

$$P_{O_2} = -\frac{1}{t_{O_2}} \left(P_{O_2} + \frac{1}{K_{O_2}} \left(q_{O_2}^{in} - K_r I_{fc} \right) \right) \tag{6}$$

B. PV Model

The equivalent circuit shown in Fig.2 is a one diode model of a solar cell which consists of a diode and a current source connected in parallel with a series resistance Rs. The current source produces the photo current Iph, which is directly proportional to solar irradiance G. The two key parameters often used to characterize a PV cell are it's short circuit current and its open circuit voltage which are provided by the manufacturer's data sheet.
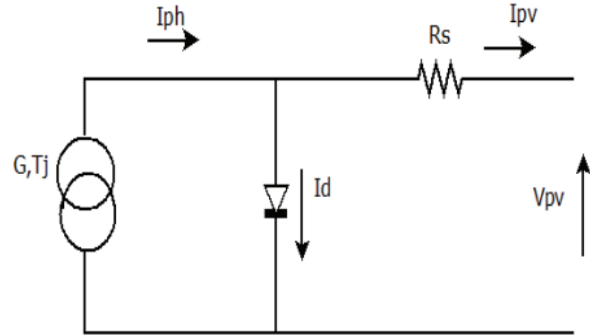

Fig.2. Equivalent solar cell model with Rs.

In the literature many MPPT techniques are available such as incremental conductance (INC), constant voltage (CV), and perturbation and observation (P&O). The P&O method has been widely used because of its simple feedback structure and fewer measured parameters. The panel voltage is deliberately perturbed (increased or decreased) then the power is compared to the power obtained before to disturbance. Specifically, if the power panel is increased due to the disturbance, the following disturbance will be made in the same direction and if the power decreases, the new perturbation is made in the opposite direction. But the demerit with P & O is the output power is oscillating in nature. Because of this reason we use the Fuzzy MPPT technique to deliver the maximum power and to eliminate perturbations in the output power.

C. Fuzzy MPPT Control

The inputs to the fuzzy MPPT control can be measured or computed from the voltage and current of solar panel. The control rules are indicated in [4]with ¨Ppv and ¨Vpv as inputs and ¨Vpvref as the output. The membership functions of input and output Variables in which membership functions of input variables ¨Ppv and ¨Vpv are triangular and has seven fuzzy subsets. Seven fuzzy subsets are considered for membership functions of the output variable ¨V pvref. These input and output variables are expressed in terms of linguistic variables (such as BN (big negative),MN (Medium negative), SN (small negative), Z (zero), SP (small positive), MP (medium positive), and BP (big positive).

D. Battery Modeling

The battery is a device which stores energy in electrochemical form. Battery is used as energy storage device in wide range of applications like hybrid electric

vehicles and hybrid power systems. In this paper, the battery energy storage is combined with hybrid PV/PEMFC distributed generation system. The battery model considered in this paper is shown in fig.3. The battery model used is based on voltage model proposed by Shepherd [4].
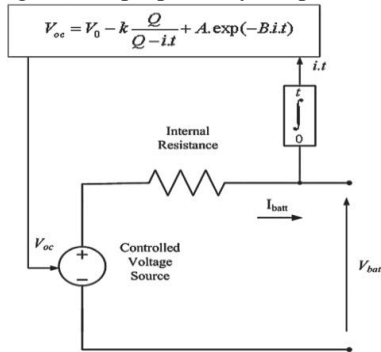

Fig. 3. Battery Model.

E. DC/DC Boost Converter Model

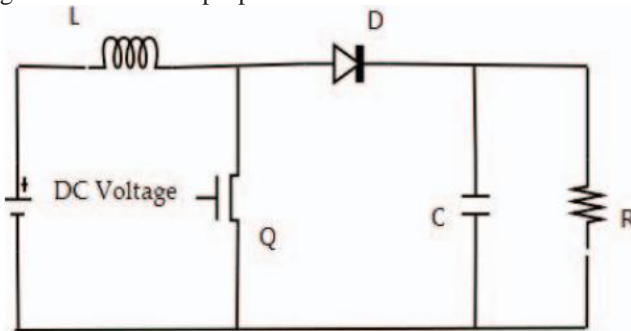While connecting a fuel cell/ PV array to the grid it is necessary to boost the voltage. The boost converter shown in fig.4 is used for this purpose.

Fig. 4. DC-DC Converter Model.

The boost converter shown in fig.4 consists of one switching device that enables it to turn on and off depending on the applied gate signal D. The gate signal for the GTO can be obtained by using fuzzy controller.

F. DC/AC Inverter Model

The dynamic model of the voltage source inverter (VSI) is used. The DC/AC inverter is shown in fig.5. To eliminate the harmonics filters are used in between grid and the inverter. The dynamic model of the VSC inverter is represented in [6]
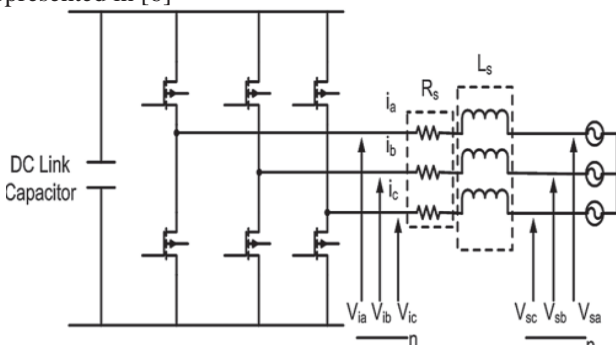

Fig.5. DC/ AC Three Phase Inverter.

III. POWER CONTROL STRATEGIES OF HYBRID SYSTEM

The power balance must always be controlled from sources to AC bus and to/from storage devices satisfying active and reactive power demand by the load. The equation (12) expresses the power balance equation that should be satisfied both at the DC-link and at the Point of Common Coupling (PCC).

$$P_{dg} = P_{pv} + P_{fc} + P_{batt}$$

$$P_{load} = P_{dg} + P_{grid}$$

$$Q_{load} = Q_{dg} + Q_{grid} \tag{7}$$

In this paper, Pload and Qload are made equal to Pref and Qref so that the hybrid power system output follows the load demand under normal loading conditions and Pgrid and Qgrid are zero. According to the control strategy proposed in this paper whenever the load exceeds the Pdg the excess load is supplied by the grid.

A. DC/DC Converter Controller using Fuzzy Logic

The unregulated dc output voltage of the fuel cell is fed to the dc/dc boost converter. The voltage is boosted depending on the duty ratio. The duty ratio is controlled by the logic controller. The input to the fuzzy logic controller is the voltage error (reference-generated) and the change in the voltage error. The fuzzy controller then generates control signal which is fed to the PWM signal generator. The boost converter generates the output voltage [5]. The membership functions for the duty ratio control of DC/DC converter is shown in fig.6 with seven linguistic variables such as, negative big, negative medium, negative small, zero, positive small, positive medium & positive big.
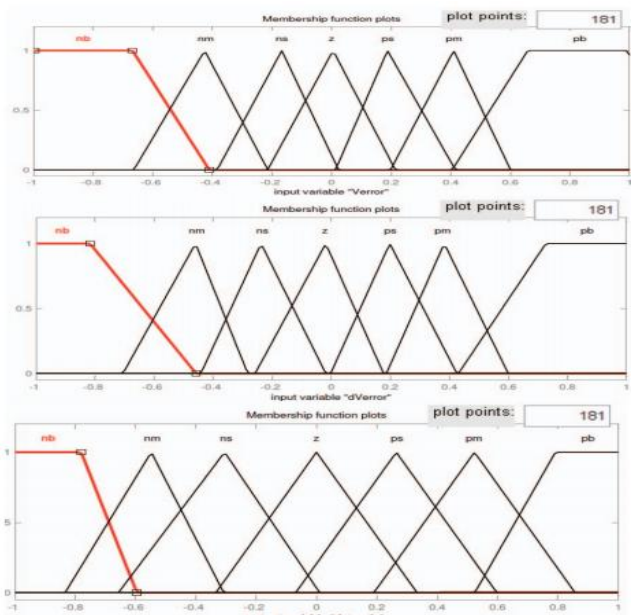

Fig.6. I/O Membership functions for DC/DC Converter.

B. DC/AC Converter Controller using Fuzzy Logic

The DC/AC converter shown in fig.5 has two controller units namely, voltage regulation control and active power control unit [6]. The inputs to the voltage regulation unit are rms voltage and its derivative and the output of the fuzzy controller is the current iqref. Similarly the inputs to the active power control unit are the active power error and its derivative and the current idref is the output of the fuzzy controller. For both the active power control and voltage regulation unit seven linguistic variables such as negative big, negative medium, negative small, zero, positive small, positive medium & positive big. The I/O membership functions are shown in fig.7 & fig 8.
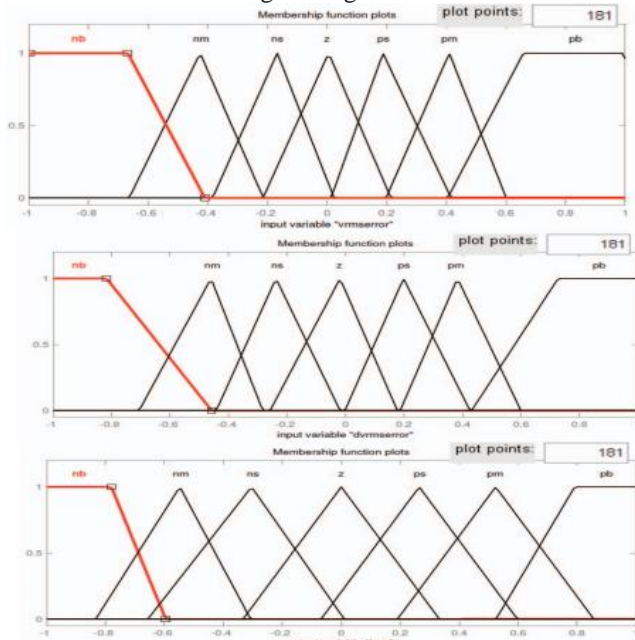
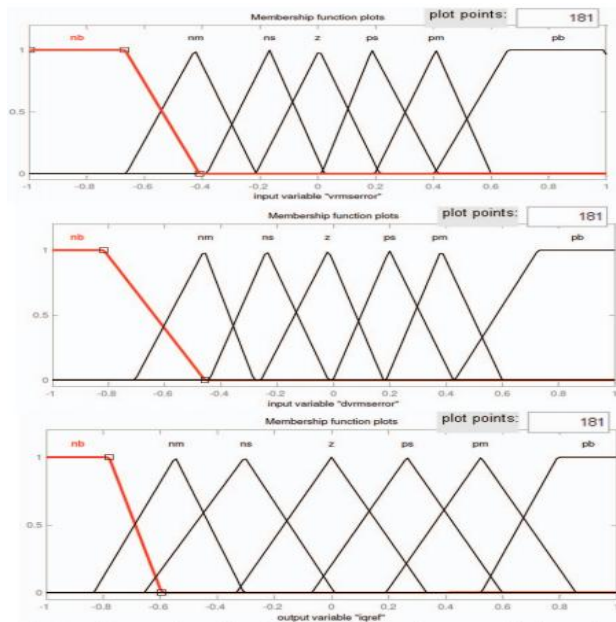**Fig.7. I/O Membership functions for voltage regulation unit.**

Fig.8. I/O Membership functions for voltage regulation unit.

IV. PERMANENT MAGNET SYNCHRONOUS MACHINE

A synchronous machine is an ac rotating machine whose speed under steady state condition is proportional to the frequency of the current in its armature. Fig.9 indicates the PMSM Cylindrical rotor and Salient rotor structures. The magnetic field created by the armature currents rotates at the same speed as that created by the field current on the rotor, which is rotating at the synchronous speed, and a steady torque results. Synchronous machines are commonly used as generators especially for large power systems, such as turbine generators and hydroelectric generators in the grid power supply. Because the rotor speed is proportional to the frequency of excitation, synchronous motors can be used in situations where constant speed drive is required. Since the reactive power generated by a synchronous machine can be adjusted by controlling the magnitude of the rotor field current, unloaded synchronous machines are also often installed in power systems solely for power factor correction. The armature winding of a conventional synchronous machine is almost invariably on the stator and is usually a three phase winding. The field winding is usually on rotor and excited by dc current, or permanent magnets. The dc power supply required for excitation usually is supplied through a dc generator known as exciter, machine which is often mounted on the same shaft as the synchronous.
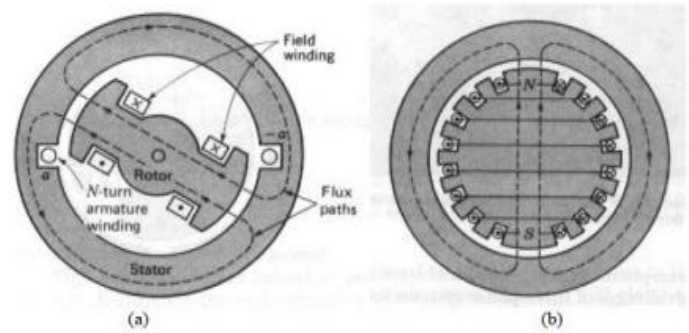
Schematic illustration of synchronous machines of (a) round or cylindrical rotor and (b) salient rotor structures

Fig.9. Cylindrical rotor and Salient rotor structures.

V. SIMULATION RESULTS

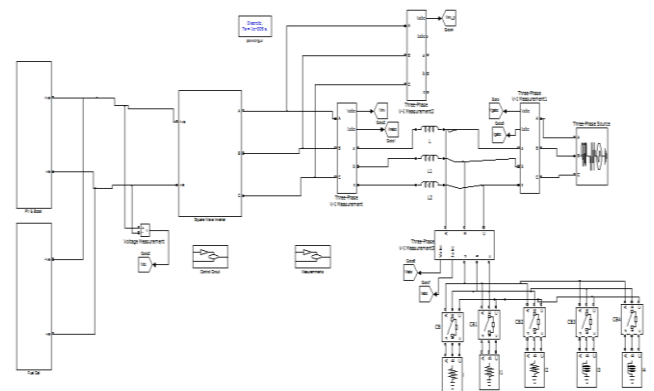Simulation results of this paper is as shown in bellow Figs.10 to 16.

Fig.10. circuit Matlab/simulation of Grid connected Hybrid system with fuzzy.

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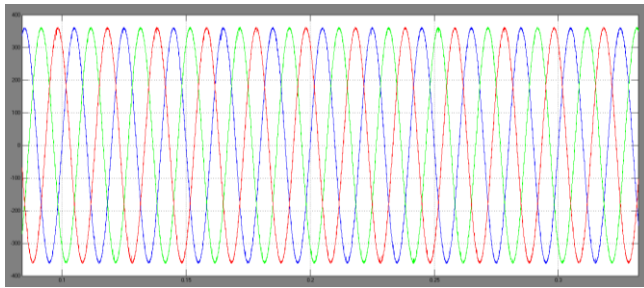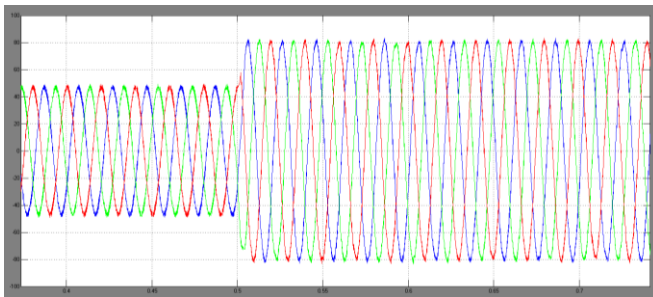

Fig 11Simulation Results of Voltage at PCC.

Fig 12Simulation Results of Currents at PCC.
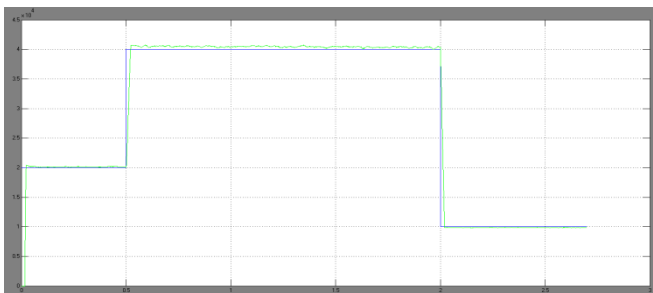

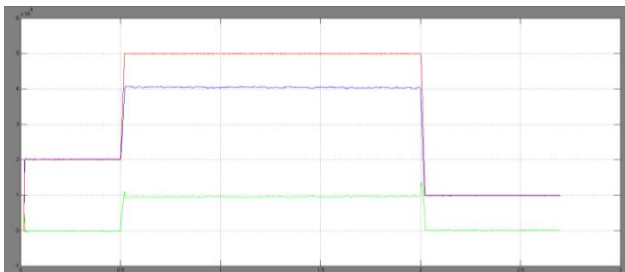Fig 13Simulation Results of Hybrid Active Power & Reference Active Power.

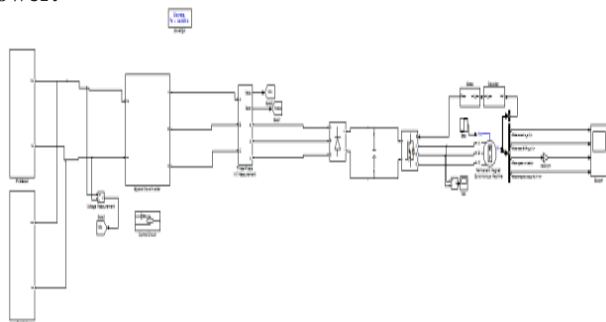Fig.14. Simulation Results of Active, Hybrid & Grid Power.

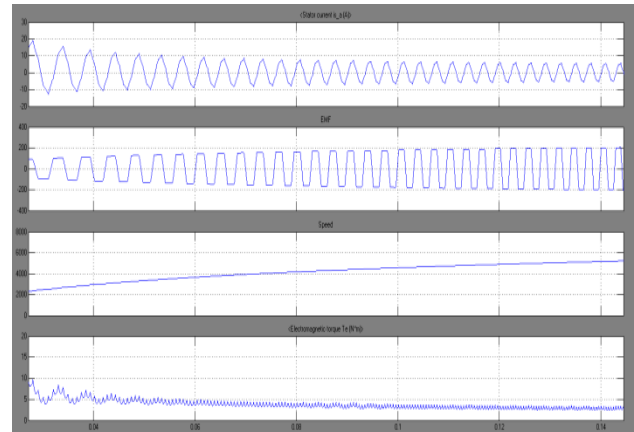Fig.15.Matlab/Simulation circuit of Grid connected Hybrid system with PMSM drive.

Fig.16. simulation wave form of Grid connected Hybrid system PMSM drive with current, EMF, torque and speed.

VI. CONCLUSION

A detailed dynamic model of PV/fuel cell based hybrid system with the control strategies are implemented. The hybrid power system considered in this work uses PV array and fuel cell system as the main sources. These sources share their power effectively to meet the load demand keeps the system stable and safe even under transient load changes. From the simulation results reported, it can be seen that the control strategy is capable of regulating the voltage and frequency within the acceptable limits irrespective of uncertainty in PV power generation and load variations. The proposed work deals with the power control strategies of a fuzzy controlled grid connected hybrid photovoltaic / proton exchange membrane fuel cell distributed generation system with battery storage. The battery responds quickly to load transients leaving the fuel cell to respond slowly. The proposed with PMSM Drive analysis of current, speed and torque can be observedusing of Matlab/Simulink.

VII. REFERENCES

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